INFRASTRUCTURAL CONSTRAINTS ON ENERGY DEVELOPMENT: THE CASE OF PAKISTAN

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Since the mid-1970s, energy planning in Pakistan has focused on (1) reducing the elasticity between economic growth and energy demand and (2) sharply increasing energy investment to augment domestic sources of supply. The Sixth Five-Year Plan (1983-1988) allocation for energy was 38 percent of total public-sector outlays. This represented a 200-percent increase over the achievements of the Fifth Plan. The Seventh Plan period (1988-1993) is continuing this trend, with energy-sector investments accounting for nearly 50 percent of the public investment program in fiscal year (FY) 1989 and 45 percent in FY 1990.

Given the present and projected shortage of energy, the emphasis on shifting resources towards expanding supply is clearly justified.[1] However, the large percentage of a small public investment program is both insufficient and unsustainable because of conflicting demands from other sectors.[2] In the short run, reducing the income elasticity of energy demand will be essential to reducing energy shortages. In this regard it is encouraging that other developing countries have been successful in loosening the link between growth and energy consumption without harmful effects upon growth.[3]

Because of its current budgetary constraints, the Pakistani government must make sure it is investing in the areas most productive in increasing the supply of energy. Clearly, increasing the supply of energy will involve not only investing directly in the energy sector, but also in a number of supportive infrastructural

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undertakings. Given this necessity, the purpose of this paper is to determine which supporting areas may have inhibited development of the sector to date. Have deficient infrastructural facilities caused energy output to lag behind the needs created by the country's recent growth? If so, what types of infrastructure are in short supply? What are the implications for government policy?

Overview

Pakistan possesses a variety of commercial and traditional energy resources for which there appears to be considerable scope for expansion. Much of the commercially viable hydroelectric potential has not as yet been tapped, and the use of coal for possible thermal power generation has only just begun to be explored. Considerable reserves of natural gas have already been proven, and prospects are good for the discovery of additional fields of oil, and especially, of gas.

Pakistan has made rapid strides in expanding its energy sector (table 1). For example, electricity output grew at a rate of 9.7 percent per annum over the 1980-1987 period. Crude oil production expanded even faster at 22.8 percent over the same interval. There have also been some marked shifts in the structure of the energy sector (table 2). It would be useful to survey the specific sources of energy.[4]

Power: Pakistan has some 30,000 megawatts (MW) of hydropower potential of which only 2,897 MW have been developed and nearly 2,000 MW are under implementation. During the period 1984-1987, thermal power increased (table 3) by 15.8 percent, (up from 6.4 percent during the 1980-1984 period). The government's Long-Term Energy Strategy (LES) calls for the development of another 8,700 MW by the year 2010. Two projects at Kalabagh and at Basha are to provide the bulk of the increase (6,000 MW). The delays so far in their launching and the as yet unresolved domestic and international issues regarding these two projects may cause a serious shortfall in future hydro supply.

Shortages in hydropower generation have led to more rapid development of thermal generation capacity. The latter has lower investment costs and shorter gestation periods yet results in higher operational costs and increased pressure on the balance of payments, as, at the margin, fuel is imported. In FY 1988, thermal generation accounted for 57 percent of total power generation, but this is now expected to increase to 66 percent by FY 1993. Almost half of thermal generation is oil based due to the failure to expand the use of domestic coal and gas for thermal generation. Pricing and political and technical issues have hampered private investment in both coal mining and coal-based power generation, while gas availabilities have remained below demand levels, with some consumers benefiting from subsidized prices well below those of comparable energy

Table 1

PAKISTAN: ENERGY COMMODITY BALANCE, 1973-1987

Indicator	1973	1980	1987	Growth Rate (in percent) 1973-1987	1973-1980	1980-1987
Crude oil products (thousand barrels)						
Production	3,062	3,566	14,999	12.0	2.2	22.8
Import	25,922	40,333	50,239	4.8	6.5	3.2
Export	5,804	10,030	2,212	–6.7	8.1	–19.4
Consumption	23,203	33,679	61,478	7.2	5.5	9.0
Natural gas (million cubic meters)						
Production	4,052	7,354	11,399	7.7	8.9	6.5
Import	0	0	0	–	–	–
Export	0	0	0	–	–	–
Consumption	4,052	7,354	11,399	7.7	8.9	6.5
Coal (thousand tons)						
Production	1,192	1,569	2,261	4.7	4.0	5.4
Import	31	98	919	27.4	17.9	37.7
Export	0	0	0	–	–	–
Consumption	1,333	1,668	3,179	6.4	3.3	9.7
Electricity (gigawatt-hours)						
Generation	8,377	14,974	28,703	9.2	8.7	9.7
Hydropower	4,335	8,714	15,250	9.4	10.5	8.3
Nuclear	304	150[a]	502	3.6	–8.5	22.3
Thermal	3,738	6,258	12,951	9.3	7.6	10.9
Net trade consumption	8,377	14,974	28,703	9.2	8.7	9.7

[a]1981.

Source: Asian Development Bank (ADB), Energy Planning Unit, Industry and Development Banks Department, *Energy Indicators of Developing Member Countries of ADB* (Manila: ADB, May 1989), p. 382.

Table 2

PAKISTAN: STRUCTURE OF THE ENERGY SECTOR, 1973-1987
(in percentage shares)

Indicator	1973	1980	1987	Growth Rate (in percent) 1973-1987	1973-1980	1980-1987
Structure of primary energy consumption	100.0	100.0	100.0	–	–	–
Oil	41.3	36.7	39.0	–0.4	–1.7	0.9
Nonoil	58.7	63.3	61.0	0.3	1.0	–0.5
Gas	37.1	41.0	35.8	–0.3	1.4	–1.9
Coal	6.7	5.2	6.9	0.2	–3.6	4.1
Primary electricity	14.9	17.1	18.2	1.4	2.0	0.9
Hydro	13.9	17.1	17.6	1.7	3.0	0.4
Nuclear	1.0	0.3[a]	0.6	–3.6	–14.0	12.2
Sectoral share of final energy	100.0	100.0	100.0	–	–	–
Residential/commercial	11.2	15.7	19.2	3.9	4.9	2.9
Oil	7.3	7.6	6.5	–0.8	0.6	–2.2
Gas	2.0	4.9	7.8	10.2	13.7	6.9
Coal	0.2	0.1	0.0	–	–9.4	–
Electricity	1.7	3.1	4.8	7.7	9.0	6.4
Industry	39.7	35.7	34.3	–1.0	–0.8	–0.6
Oil	4.3	2.5	8.0	4.5	–7.5	18.1
Gas	22.9	22.9	16.1	–2.5	0.0	–4.9
Coal	7.9	6.4	5.6	–2.4	–3.0	–1.9
Electricity	4.6	3.9	4.5	–0.2	–2.3	2.1
Transport	21.3	25.9	26.3	1.5	2.8	0.2
Agriculture	7.5	4.8	3.6	–5.1	–6.2	–4.0
Others	12.5	8.4	3.0	–9.7	–5.5	–13.7
Nonenergy	7.8	9.5	13.7	4.1	2.9	5.4

[a]1981.

Source: Asian Development Bank (ADB), Energy Planning Unit, Industry and Development Banks Department, *Energy Indicators of Developing Member Countries of ADB* (Manila: ADB, May 1989), p. 383.

Table 3

PAKISTAN: INSTALLED GENERATING CAPACITY OF ELECTRIC POWER UTILITIES, 1973-1987
(in megawatts)

					Growth Rate (in percent)			
Indicator	1973	1980	1984	1987	1973-1987	1973-1980	1980-1984	1984-1987
Thermal	1,068	1,814	2,325	3,615	9.1	7.9	6.4	15.8
WAPDA[a]	654	1,141	1,442	2,477	10.0	21.0	6.0	19.8
KESC[a]	–	673	883	1,138	–	–	7.0	8.8
Hydropower (WAPDA)[a]	767	1,567	2,548	2,901	10.0	10.7	12.9	4.4
Nuclear (KANUPP)[a]	137	137	137	137	0.0	0.0	0.0	0.0
Total	1,972	3,518	5,010	6,654	9.1	8.6	9.2	9.9

[a]WAPDA = Water and Power Authority; KESC = Karachi Electric Supply Corporation; KANUPP = Karachi Nuclear Power Plant.

Source: Asian Development Bank (ADB), Energy Planning Unit, Industry and Development Banks Department, *Energy Indicators of Developing Member Countries of ADB* (Manila: ADB, May 1989), p. 387.

sources. In the coal sector, difficulties may continue as the financial and economic viability of the main coal deposits to be used for power generation have not yet proven sufficient to attract private investment.

As far as electricity-generating infrastructure is concerned, one important area for efficiency enhancement concerns excessive losses in the transmission and distribution systems which, with few exceptions in the Asian countries, ranged from 13 percent to as high as 30 percent of power generated in Pakistan, Afghanistan, Bangladesh, Indonesia, Burma, and Nepal. A large part of such losses are of a technical nature, although it is very difficult to establish appropriate yardsticks and targets as system losses depend greatly on generation plant and fuel mixes, load factors, consumer and other demand characteristics, and other associated costs.[5]

Oil: Pakistan's oil production—about 2.6 million metric tons (mt) of crude oil per year—is slightly over one-fourth of the country's total consumption of nearly

10 million mt. Refining capacity increased (table 4) by only 1.3 percent per annum over the 1980-1987 period (versus 7.6 percent per annum during 1973-1980). Moreover, given the limited volume of proven reserves, reserves would be exhausted in five to seven years at the current rate of extraction.

Thus, oil imports are likely to continue increasing and will put a serious burden on the balance of payments. In particular, if the share of electricity produced by other sources (hydro, gas, and coal) is not expanded, power supplies will continue to be in great shortage. At this time, oil products constitute the main source of thermal power generation and their share is expected to increase in the coming years.[6]

While imported gasoline for the transport sector will be difficult to replace (except, on a limited basis, by natural gas), the massive use of oil products for power generation in a country with abundant hydro, gas, and coal resources is sub-optimal; in the short run, however, it is difficult to switch to hydropower generation because of long lead times and substantial capital costs of hydroelectric investments. Given the continued high demand for oil products, additional and expanded exploration and development efforts, to be financed by private-sector investment, should be encouraged.

Gas: Prospects for the gas sector are brighter as proven reserves are large (16 trillion cubic feet) and probable reserves (6.3 trillion cubic feet) are also significant. As is the case of hydro resources, however, the rate at which these gas resources are developed is slower than the resource base warrants. This is due to the limited interest of the private oil industry in gas exploration; as a result, the government's efforts to attract private investment have had only moderate success. Contributing factors are the limited capacity of government institutions charged with promoting private investment in the sector and the scarce resources for public investment. Even more importantly, gas use is constrained by the inadequacy of transmission infrastructure.

Projects to upgrade and expand transmission infrastructure are being undertaken, but this requires massive capital investment. As in the case of power, pricing is a major issue for the gas sector. In particular, energy prices have increased at rates considerably below the overall consumer or wholesale prices indices (table 5). Subsequently, gas prices for practically all consumers continue to be well below the equivalent international price for oil products, and in the case of gas used in the production of fertilizers, the price is even lower.

Of the domestic production of natural gas, about 25 percent is consumed for fertilizer production, 36 percent for power generation, and the balance is used by households and commercial and industrial users. Natural gas generates only a third of total electricity in the country as some plants designed to operate as combined cycle facilities, but designed for optimum use of natural gas, are burning mostly oil because of the current unavailability of gas at their location.[7]

Table 4

PAKISTAN: REFINING CAPACITY, 1973-1987
(in thousand barrels per calendar day)

Indicator	1973	1980	1987	Growth Rate (in percent) 1973-1987	1973-1980	1980-1987
Refinery capacity						
Crude distillation capacity	75	125	137	4.4	7.6	1.3
Pakistan Refinery Ltd.	51	51	57	0.8	0.0	1.6
National Refinery Ltd.	12	43	43	9.5	20.0	0.0
Attock Refinery Ltd.	11	31	37	9.1	16.0	2.6
Catalytic reforming	2.5	5.0	5.8	6.2	10.4	2.1
Refinery activities						
Refinery throughput	68	89	116	3.9	3.9	3.9
Refinery output	65	85	111	3.9	3.9	3.9
Light distillates	6	10	17	7.7	7.6	7.9
Middle distillates	31	37	51	3.6	2.6	4.7
Heavy distillates	28	38	43	3.1	4.5	2.2
Domestic requirements[a]	75	98	169	6.0	3.9	8.1
Performance indicators (%)						
Utilization rate[a]	91.0	71.5	84.7	–0.5	–3.4	2.4
Self-reliance ratio[a]	86.4	87.1	65.3	–2.0	0.1	–4.0

[a]Petroleum domestic requirements include domestic consumption plus international bunkers; utilization rate is defined as the ratio of refinery throughput over crude distillation capacity; self-reliance ratio is defined as the ratio of refinery output over domestic requirements.

Source: Asian Development Bank (ADB), Energy Planning Unit, Industry and Development Banks Department, *Energy Indicators of Developing Member Countries of ADB* (Manila: ADB, May 1989), p. 388.

Table 5

PAKISTAN: ENERGY PRICE INDICES, 1973-1987
(in percentage shares)

Indicator	1973	1980	1987	Growth Rate (in percent) 1973-1987	1973-1980	1980-1987
General price indices						
Consumer prices	100.0	241.0	389.0	10.2	13.4	7.1
Wholesale prices	100.0	218.0	354.0	9.4	11.8	7.2
GDP deflator[a]	100.0	238.0	384.8	10.1	13.2	7.1
Energy price indices based on original unit prices						
Oil products	100.0	507.0	631.0	14.1	26.1	3.2
Motor spirit	100.0	324.0	520.0	12.5	18.3	7.0
High octane	100.0	409.0	557.0	13.1	22.3	4.5
Kerosine	100.0	568.0	682.0	14.7	28.2	2.6
Diesel	100.0	424.0	583.0	13.4	22.9	4.7
Fuel oil	100.0	521.0	825.0	16.3	26.6	6.8
Natural gas	100.0	143.0	82.0	–1.4	5.2	–7.6
Electricity	100.0	321.0	441.0	11.2	18.1	4.6
Energy price indices based on tons of oil equivalent prices						
Oil products	100.0	476.0	629.0	14.0	25.0	4.1
Natural gas	100.0	142.0	86.0	–1.1	5.1	–6.9
Electricity	100.0	321.0	441.0	11.2	18.1	4.6
Average energy	100.0	394.0	462.0	11.6	21.6	2.3

[a]GDP = gross domestic product.

Source: Asian Development Bank (ADB), Energy Planning Unit, Industry and Development Banks Department, *Energy Indicators of Developing Member Countries of ADB* (Manila: ADB, May 1989), p. 385.

Coal: Total recoverable reserves of coal are estimated at 1,400 million tons, of which 175 million tons are proven. Despite the technical sustainability of Pakistan's coal for the production of electricity and industrial steam, its share in the supply of commercial energy has remained stagnant at a very low level. This was mainly due to the pricing policy prior to 1985 when the price of fuel oil and natural gas was kept low. Although these prices were increased subsequently, development of coal deposits has not yet taken place. The main reasons for this delay include: (1) the absence of a stable market for large-scale use (a large coal-fired thermal plant is now to be constructed but might end up using imported coal); (2) the inadequacy of laws governing coal exploration and development by the private sector; and (3) the failure of the public sector to develop publicly held concessions.[8]

The Seventh Five-Year Plan aims at taking bold measures to resolve issues which are an obstacle to the development of an adequate and viable national energy system. The major objectives of the plan are to (1) substantially increase electricity supply to sustain the projected growth in different sectors of the economy, eliminate load-shedding, and electrify most of the rural areas, (2) accelerate the exploration and development of domestic oil, coal, gas, hydroelectric, and renewable resources, (3) reduce the import burden by increasing the use of indigenous fuels like coal and gas in power generation and other sectors of the economy, (4) make conservation and efficient use of energy a common practice in all sectors and reduce power system losses, (5) establish an efficient load-management system for optimum use of generated power to reduce the peak demand and to contribute towards minimizing load shedding, (6) draw upon the financial resources and expertise of the private sector to a much greater degree for energy development and production, (7) rationalize energy consumer prices, remove structured anomalies, generate funds for new energy investments, provide incentives to conserve energy, and encourage desirable substitutions among different fuels, (8) strengthen the financial capacity of the government organizations to self-finance their investment programs and reduce the burden on government resources, (9) increase rural energy supplies, and (10) develop energy-sector manpower and improve the effectiveness of its institutions.[9]

An important aspect of the Seventh Plan program will be the significant role played by the private sector:

> The contribution of the private sector in power system development is expected to be over 2,000MW. This may include incentives such as designating areas for private sector power projects which have been identified, defining conditions of purchase of power by WAPDA and KESC, assigning a major portion of Lakhra coal fields for private power generation and designating selected dormant gas fields for private sector power development.[10]

Other than this statement, however, the plan is vague as to how the government intends to induce private-sector investment in the energy sector.

Impact of Infrastructure

Clearly, one way to stimulate private investment in energy is to make that investment more profitable. While the Seventh Five-Year Plan does not go into detail as to the effectiveness of infrastructure in contributing to an expansion of energy output, it is clear to most observers that infrastructural shortages are likely to have played a significant role in slowing down the development of the energy sector in recent years.[11]

This analysis is usually based on impressionistic assessments. In addition, there is little or no information as to the relative productivity of different types of infrastructure in stimulating this sector's output. More importantly, qualitative assessments provide no insights as to the direction of causation—has infrastructural development stimulated increased levels of output by making energy sources more accessible? Or, instead, has infrastructure been a chronic bottleneck to output? That is, has the government responded with increased provision of infrastructure only after infrastructure deficiencies have severely constrained output and (presumably) the flow of private capital into the sector?

A major issue in the analysis of the role of infrastructure in Pakistan's post-1971 development therefore centers around the direction of causation: has infrastructure initiated growth in energy production or has it simply responded to the needs created by an expanding economy?

Among economists there is a broad spectrum of viewpoints, some of them diametrically opposed to the other, concerning the role of infrastructure in the development process.[12] There is consensus, however, as to the need for a certain level of basic infrastructure facilities, since ultimately infrastructure must be a limiting factor without which no development process could take place even if other development processes were present. However, opinions as to infrastructure's precise role in the growth process beyond this point differ greatly.

Some economists such as D. R. Glover and J. L. Simon[13] and P. C. Frederiksen[14] take the view that the role of infrastructure is simply to relieve "tensions" generated by supply and demand patterns as well as bottleneck pressures. Another (smaller) group of economists led by F. Voigh maintains that alternations in infrastructure exert a follow-on influence on investment and growth.[15]

The majority of economists seem to take a middle position between these two more or less diametrically opposed views.[16] Some of them consider infrastructure to be a function of the level of development; in other words, the more economically and socially backward a potential development area, the stronger the impulses emanating from improvements in the stock of infrastructure. Others feel that the reciprocal relationship between changes in infrastructure and socio-economic developments is such that the problem of cause and effect is not open to solution.

However, most economists agree that if infrastructure investments, labor market planning, and educational planning are uncoordinated, they are likely to yield conflicting results or, at any rate, outcomes that could eventually lead to undesirable solutions. Much of the confusion as to the role of infrastructure in energy development occurs because infrastructure itself is not homogeneous. In addition, it is quite likely that the contribution to output from infrastructure investment will be dependent on the stock of supporting factors, the composition and level of which are likely to vary somewhat over time.

Complicating the issue is the fact that for many years economists were reluctant to discuss the issue of causality from a statistical perspective. However, recently several statistical tests are gaining wider acceptance in addressing issues of this type. The original and most widely used causality test was developed by C.W.J. Granger.[17] Applied to the situation at hand, infrastructure causes (in the Granger sense) growth in energy output, if that sector's growth can be predicted more accurately by past values of infrastructure investment than by past values of its output. To be certain that causality runs from infrastructure to output, past values of infrastructure must also be more accurate than past values of output at predicting infrastructure expenditures.[18]

More formally, four cases are possible. (a) *Infrastructure causes output* when the prediction error for growth (of energy output) decreases when infrastructure investment is included in the energy growth equation. In addition, when energy growth is added to the infrastructure equation, the final prediction error should increase. (b) *Output causes infrastructure* when the prediction error for energy output increases when infrastructure is added to the regression equation for output and is reduced when output is added to the regression equation for infrastructure. (c) *Feedback* occurs when the final prediction error decreases when infrastructure is added to the output equation, and the final prediction error decreases when energy output is added to the infrastructure equation. (d) *No relationship* exists when the final prediction error increases both when infrastructure is added to the energy output equation and when energy output is added to the infrastructure equation.

These patterns also imply something about the extent to which inadequate stocks of infrastructure may constrain output in the transportation/communications sector. Extending the original ideas of A. O. Hirschman, infrastructure development can initiate inputs used in production.[19] This is the process referred to by Hirschman as "development via excess capacity" (of social overhead capital). Conversely, lagging infrastructure may increase costs of producing and result in slowing output and investment. In this situation the authorities are under pressure to expand infrastructure to "catch up" with the stock of directly productive capital. This route is often referred to as "development via shortage" (of social overhead capital).[20] As Benjamin Higgins

> Either method of unbalanced growth yields an "extra dividend" of "induced, easy-to-take or compelled decisions resulting in additional investment and output." Balanced growth (of social overhead capital and directly productive activity) is not only unattainable in most underdeveloped countries, it may not even be desirable. The rate of growth is likely to be faster with chronic imbalance, precisely because of the "incentives and pressures" it sets up.[21]

From the above, it follows that at least four possible situations characterize the relationship between infrastructure investment and energy output in Pakistan.

1. Infrastructure Causes Output: This pattern is likely to reflect a situation where infrastructure is in excess (or non-constraining); the lower costs stemming from its provision result in follow-on investment and output. In this situation, infrastructure could be expected to have a high degree of linkage with productive factors and thus produce a strong output response.

2. Growth Causes Infrastructure: Here infrastructure is lagging and responds to the needs created by previous growth. In this situation, infrastructure is likely to be a constraint on that output. This may have occurred in Pakistan, particularly during periods (such as the 1980s) when the economy expanded rapidly. Although infrastructure expanded during this period, it may still (given the needs) have been insufficient to produce a substantial stimulus to energy output.

3. Feedback: Output and infrastructure become interdependent, perhaps reflecting a situation where infrastructure is likely a binding constraint on energy output. Once increased, infrastructure is adequate (relative to needs) to provide a positive stimulus to further output.

4. No Relationship: As it implies, infrastructure is not a constraint on energy output, nor does it possess or create the type of linkages needed to induce increases in output or investment.

The second and third patterns imply that some threshold level of infrastructure may be necessary before positive economic results can be obtained from expanding this type of capital.

Operational Procedures

The Pakistani Government does not publish data on the stock of and increments to the country's infrastructure. However, following the procedure of Mario Blejer and Mohsin Khan, it is possible to approximate increments to the nation's infrastructural base.[22] The basic assumption underlying these proxies is that infrastructure investment is an ongoing process that moves slowly over time and cannot be changed very rapidly.

The first of the two approaches takes the trend level of real public-sector investment as representing the long-term or infrastructural component. In the discussion that follows, this measure is referred to as "estimated infrastructure." In computing this measure of infrastructure, we have used a linear trend. Deviations of real public-sector investment from the trend are assumed to correspond to noninfrastructural investment.

A second approach is to make the distinction between types of public investment on the basis of whether the investment is expected or not. Again, it is assumed that expected, or anticipated, public investment is closer to the long-term or infrastructural component. If deterioration is occurring in the country's stock of infrastructure, this measure may be a more accurate proxy than that obtained using the trend method; it was the one used in the computations in this study.

The data for investment upon which the infrastructure expenditures were calculated were derived from figures in two World Bank publications: *Pakistan: Current Economic Situation and Prospect—Report No. 9283-PAK* (March 22, 1991) and *Pakistan: Review of the Sixth Five-Year Plan* (1983). Gross domestic product (GDP) and the GDP price deflator are from various issues of the International Monetary Fund's *International Financial Statistics Yearbook.* All variables were deflated by the GDP deflator and are in constant 1985 prices. For best statistical results, the variables were transformed into their logarithmic values.[23]

A major conceptual problem in a study of this sort is that public infrastructure is usually not specifically directed toward one particular sector. Energy, for example, might be used by a number of sectors, some of which perhaps were not even considered in the original feasibility studies. Because of this element, a number of different measures of infrastructure (and investment) were used: (1) total public investment (and infrastructure); (2) energy; (3) public enterprises including railroads and post office/telephone/telegraph; and (4) general government (including federal, provincial, and local governments).

As purely a basis of comparison, several measures of private investment (total private and private in manufacturing) were also included in the study.

Relationships between infrastructure expenditures and the economy were considered valid if they were statistically significant at the 95-percent level of confidence. That is, if 95 percent of the time we could conclude that they had not occurred by pure chance, we considered them statistically significant.

There is no theoretical reason to believe that infrastructure and the economy have a set lag relationship—that is, they impact on one another over a fixed time period. The period could be rather short run, involving largely the spin-off from construction, or longer term as either term expands from the stimulus provided by the other. To find the optimal adjustment period of impact, lag structures of up to six years were estimated. The lag structure with the highest level of statistical significance was the one chosen best to depict the relationship under consideration (the optimal lag reported in tables 2, 3, and 4).

Results

The analysis of total manufacturing produced several interesting patterns as seen in tables 6 and 7.

1. The dominant pattern is one of feedback; that is, increases in infrastructure and investment tend to lead (usually) to an expansion in energy output. In turn, this expanded output induces further increases in investment and infrastructure. It should be noted, however, that except for direct investment in the energy sector, most of these effects were rather weak.

2. As might be anticipated, increases in public *infrastructure* in the electricity, gas, and water sector produced a strong follow-on expansion of energy production. However, it should be noted that public *investment* in the sector produced only a weak expansion in output.

3. Expansion in public enterprise (including post office, telephone, and telegraph, together with the railroads) infrastructure is one exception to the general rule noted above. However, while public enterprise infrastructure produced a moderate increase in power output, investment by these enterprises only weakly stimulated increased energy production.

4. Infrastructure expansion by semi-public organizations (including the energy sector) also produced a fairly strong increase in energy production (although investment by these enterprises was not nearly as effective in this regard).

5. Indus Basin investment and infrastructure expansion—an area where one might expect a number of complementary relationships with energy development—was actually associated with a decrease in energy production.

6. General government infrastructure and investment (including that by federal, provincial, and local authorities) was only weakly associated with energy production.

7. However, federal infrastructure responded fairly strongly to increased levels of energy production; that is, investment by federal authorities did not expand energy output. Instead, capital formation by this level of government responded to past increases in energy production.

The general prevalence of feedback relationships suggests that infrastructure development may have lagged somewhat behind the needs created by economy—at least it is clear that infrastructure and public investment have not initiated an expansion of the energy sector. At best, public investment and infrastructure have expanded, but usually only after induced by increased levels of energy production (and presumably the pressures that have been associated with power shortages, load shedding, etc.).

Table 6

PAKISTAN: INTERACTION OF PUBLIC INVESTMENT, INFRASTRUCTURE, AND THE ENERGY SECTOR, 1972-1990[a]

Optimal Lag (Years) Final Prediction Error ( )	Causation Patterns A	B	C	D	Dominant Pattern
Electricity, gas, and water output					
Total public investment	3 (0.12E–1)	4 (0.84E–2)	2 (0.82E–2)	4 (0.63E–2)	Feedback (+w, –w)
Total public infrastructure	3 (0.12E–1)	4 (0.11E–1	2 (0.67E–2)	1 (0.64E–2)	Feedback (+w, +w)
Public investment electricity and gas	3 (0.12E–1)	4 (0.78E–2)	4 (0.89E–1)	4 (0.23E–1)	Feedback (+w, +w)
Public infrastructure electricity and gas	3 (0.12E–1)	4 (0.12E– 2)	4 (0.81E– 1)	4 (0.82E– 1)	Infrastructure →Output (+vs)
Public enterprises investment	3 (0.12E–1)	4 (0.48E– 2)	4 (0.39E– 1)	4 (0.20E– 1)	Feedback (+w, +w)
Public enterprises infrastructure	3 (0.12E–1	3 (0.44E– 2)	1 (0.25E– 1)	3 (0.14E– 1)	Feedback (+m, +w)
Semi-public organization investment	3 (0.12E–1)	1 (0.82E– 2)	2 (0.17E– 1)	4 (0.17E– 1)	Investment →Output (+w)
Semi-public organization infrastructure	3 (0.12E–1)	4 (0.34E–2)	1 (0.15E–1)	1 (0.16E–1)	Infrastructure →Output (+s)
Post office, telegraph investment	3 (0.12E–1)	2 (0.80E–2)	1 (0.84E–1)	3 (0.44E–1)	Feedback (+w, +m)
Post office, telegraph infrastructure	3 (0.12E–1)	1 (0.73E–2)	1 (0.67E–1)	4 (0.20E–1)	Feedback (+w, +vw)
Indus Basin investment	3 (0.12E–1)	2 (0.59E–2)	1 (0.22E–0)	3 (0.19E–0)	Feedback (–w, –w
Indus Basin infrastructure	3 (0.12E–1)	1 (0.56E–2)	1 (0.12E–0)	4 (0.88E–1)	Feedback (–m, –w)

[a]Summary of results obtained from Granger causality tests. A Hsiao procedure was incorporated to determine the optimal lag. All variables estimated in logarithmic form. Regression patterns: A = output on output; B = investment on output; C = investment on investment; D = output on investment. The dominant pattern is that with the lowest final prediction error. The signs (+, –) represent the direction of impact. In the case of feedback the two signs represent the lowest final prediction error of relationships B and D. Each of the variables was regressed with 1-, 2-, 3-, and 4-year lags. Strength assessment (s = strong; m = moderate; w = weak) based on the size of the standardized regression coefficient and t-test of statistical significance.

Table 7

PAKISTAN: INTERACTION OF GENERAL GOVERNMENT INVESTMENT, INFRASTRUCTURE, AND THE ENERGY SECTOR, 1972-1990[a]

Optimal Lag (Years) Final Prediction Error ( )	Causation Patterns A	 B	 C	 D	Dominant Pattern
Electricity, Gas, and Water Output					
General government investment	3 (0.12E–1)	2 (0.97E–2)	1 (0.10E–2)	1 (0.65E–2)	Feedback (+w, +m)
General government infrastructure	3 (0.12E–1)	4 (0.61E–2)	1 (0.77E–2)	1 (0.61E–2)	Feedback (+w, +w)
Federal government investment	3 (0.12E–1)	2 (0.13E–1)	1 (0.19E–1)	1 (0.14E–1)	Output →Investment(+m)
Federal government infrastructure	3 (0.12E–1)	4 (0.85E–2)	1 (0.13E–1)	2 (0.10E–1)	Feedback (+w, +vw)
Provincial government investment	3 (0.12E–1)	3 (0.85E–2)	2 (0.13E–1)	3 (0.67E–2)	Feedback (+w, +w)
Provincial government infrastructure	3 (0.12E–1)	4 (0.63E–2)	2 (0.96E–2)	4 (0.74E–2)	Feedback (+w, +vw)
Local government investment	3 (0.12E–1)	1 (0.92E–2)	1 (0.33E–1)	1 (0.20E–2)	Feedback (–w, +m)
Local government infrastructure	3 (0.12E–1)	3 (0.98E–2)	1 (0.37E–2)	2 (0.25E–1)	Feedback (+vw, +vw)

[a]Summary of results obtained from Granger causality tests. A Hsiao procedure was incorporated to determine the optimal lag. All variables estimated in logarithmic form. Regression Patterns: A = output on output; B = investment on output; C = investment on investment; D = output on investment. The dominant pattern is that with the lowest final prediction error. The signs (+,–) represent the direction of impact. In the case of feedback the two signs represent the lowest final prediction error of relationships B and D. Each of the variables was regressed with 1-, 2-, 3-, and 4-year lags. Strength assessment (s = strong; m = moderate; w = weak) based on the size of the standardized regression coefficient and t-test of statistical significance.

This is consistent with the finding by T. Riaz that

> . . . at an early stage of economic development each country relies heavily on non-commercial sources of energy and that the subsequent process of industrialization is highly energy-intensive. In statistical terms, one would expect a negative intercept and a positive slope (of a regression of energy use and Gross National Product) for a developing country like Pakistan, whereas a developed country would be expected to have a positive intercept and positive slope which is fairly shallow as it must use large amounts of commercial energy to sustain itself—but because of the economic infrastructure, it can use its energy more efficiently.[24]

Conclusions

The above assessment of the interrelationship between public investment and energy development suggests serious output constraints, largely related to insufficient development of domestic resources. This, in turn, is related to low levels of investment which have been financed, nearly exclusively, by the federal government. In fact, energy-sector investments (mostly WAPDA—Water and Power Development Authority) accounted for nearly 50 percent of the public investment program in FY 1989 and 45 percent in FY 1990.

The large percentage of a small public investment program is both insufficient and unsustainable because of conflicting demands from other sectors. Therefore, in addition to higher domestic resource mobilization by the public sector (and by the energy-sector companies), increased private-sector investment in energy is essential.[25] If the private sector is not responsive, the government will have to rely more and more on demand-side energy policies as a means of equilibrating the power markets.

NOTES

[1]See, for example, T. Riaz, "Energy and Economic Growth: A Case Study of Pakistan," *Energy Economics*, July 1987, pp. 195-204, and Hafiz A. Pasha, Aisha Ghaus and Salman Malik, "The Economic Cost of Power Outages in the Industrial Sector of Pakistan," *Energy Economics*, October 1989, pp. 301-18.

[2]The World Bank, *Pakistan: Current Economic Situation and Prospects—Report No. 9283-PAK* (Washington, D.C.: The World Bank, March 22, 1991), p. 36.

[3]The World Bank, *Pakistan: Review of the Sixth Five-Year Plan* (Washington, D.C.: The World Bank, 1963), p. 69.

[4]The survey which follows, tracing Pakistan's progress in energy development, draws heavily on The World Bank, *Pakistan: Current Economic Situation and Prospects—Report No. 9283-PAK*, pp. 34-6.

[5]United Nations, Economic and Social Commission for Asia and the Pacific, *Economic and Social Survey of Asia and the Pacific, 1990* (New York: United Nations, 1991), p. 136.

[6]The World Bank, *Pakistan: Current Economic Situation and Prospects-Report No. 9283-PÀK*, p. 35.

[7]Ibid., p. 36.

[8]Ibid.

[9]Government of Pakistan, *Seventh Five-Year Plan, 1988-1993 & Perspective Plan, 1988-2003* (Lahore: Planning Commission, 1988), p. 195.

[10]Ibid., p. 196.

[11]See, for example, Charles K. Ebinger, *Pakistan: Energy Planning in a Strategic Vortex* (Bloomington, Indiana: Indiana University Press, 1981).

[12]The following draws on Robert E. Looney and Peter C. Frederiksen, "The Regional Impact of Infrastructure Investment in Mexico," *Regional Studies*, no. 4, 1981, pp. 285-96.

[13]D. R. Glover and J. L. Simon "The Effect of Population Density on Infrastructure: The Case of Road Building," *Economic Development and Cultural Change*, April 1975, pp. 453-68.

[14]P. C. Frederiksen, "Further Evidence on the Relationship Between Population Density and Infrastructure: The Philippines and Electrification," *Economic Development and Cultural Change*, July 1981, pp. 749-58.

[15]F. Voigh, "The Tasks of Modern Transport Science," *International Journal of Transport Economics*, April 1974, pp. 255-62.

[16]See, for example, Neils Hansen, "Unbalanced Growth and Regional Development," *Western Economic Journal*, December 1965, pp. 150-62, and the essays contained in Gary Fromm, editor, *Transport Investment and Economic Development* (Washington, D.C.: The Brookings Institution, 1965).

[17]C.W.J. Granger, "Investigating Causal Relations by Econometric Models and Cross-Spectral Methods," *Econometrica*, June 1969, pp. 424-38.

[18]It should be noted that this technique is not without its critics. For an excellent critique of the causality issue, see M. Gonzi, "The New Pelgrave on Causality—A Critical Appraisal," *International Journal of Transport Economics*, February 1989, pp. 91-6.

[19]A. O. Hirschman, *The Strategy of Economic Development* (New Haven: Yale University Press, 1958), especially chapters 3-5.

[20]Benjamin Higgins, *Economic Development* (New York: W. W. Norton, 1959), p. 405.

[21]Ibid.

[22]Mario I. Blejer and Mohsin S. Khan, "Public Investment and Crowding Out in the Caribbean Basin Countries," in *The Economics of the Caribbean Basin*, eds. Michael Connolly and John McDermott (New York: Praeger Publishers, 1985), pp. 219-36.

[23]The underlying reasons involve the assumption of stationary conditions. See C. Hsiao, "Autoregressive Modeling and Money-Income Causality Detection," *Journal of Monetary Economics*, December 1981, pp. 85-106, and W. Joerding, "Economic Growth and Defense Spending: Granger Causality," *Journal of Development Economics*, April 1986, pp. 35-40.

[24]T. Riaz, "Pakistan: Energy Consumption and Economic Growth," *The Pakistan Development Review*, summer-autumn 1984, p. 434.

[25]The World Bank, *Pakistan: Current Economic Situation and Prospects—Report No. 9283-PAK*, p. 36.